DIGITAL HEALTH - DIGITAL 2D/3D PRINTING OF PERSONALIZED MEDICATION

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ABSTRACT

Without any doubt the young technology of additive manufacturing, including 2D and 3D printing, has been changing the world. A wide spectrum of objects in medical and pharmaceutical field can already be successfully printed. This ranges from a detailed figure in the micrometer regime to a full size residential house unit made from concrete [Sakin et al., 2017; Doherty et al., 2020]. In the pharmaceutical sector, additive manufacturing offers the option of medication customization [Pravin et al., 2018]. Integrating this new technology has several advantages over the current, well-established but outdated "one-size-fits-all" approach. Besides avoiding medication errors, printing tailored oral dosage forms is financially attractive for small scale on-demand production [Awad et al., 2018]. The development of dosage forms, production of sample batches and modification of samples can be done with little effort compared to generic powder-pressed pills which require heavy pharmaceutical machinery [Awad et al., 2018; Dachtler et al., 2020]. To further progress and to create the legal framework for the approval of additively manufactured drugs it requires a paradigm change of stakeholders who have the power to make decisions and changes [Horst et al., 2019].

Keywords: Healthcare Digitalization, Pharmaceutical Industry, Additive Manufacturing, 2D/3D Printing.

BENEFITS OF PERSONALIZED MEDICATION

Currently, the majority of pharmaceutical formulations have a predetermined dosage of one or more active ingredients [Rahman et al., 2018]. This is not tailored to the physiological constitution of the patient. Dosing drugs optimally depends on genetic, metabolic and gender-specific properties. Highly potent drugs in particular have a narrow therapeutic window, which varies from patient to patient. This calls for an individual treatment through personalized healthcare. Generic drugs do not meet the requirements for treating patients immaculately and there is a possibility of non-optimal or incorrect dosing [Reiner et al., 2020]. A wide variety of dosage forms and combinations of active pharmaceutical ingredients with tailored release kinetics need to be administered. This way, optimal therapy success is guaranteed and the risk of perilous medication errors is minimized. The problem of wrong medication should not be underestimated, as it is the third leading cause of death in the USA after cardiovascular diseases and cancer [Makary et al., 2016].

The decentralized production of drugs avoids complex process steps involved in the "classic" production of solid dosage forms. The idea includes patient data being transmitted in digital form, for example from the attending physician, directly to the 2D/3D printer in a pharmacy. The diagnosis is linked directly to individual medication. Small batches are produced cost-efficiently as required, which prevents drug bottlenecks or waste of active ingredients [Fasila et al., 2008]. Stocks of rare drugs can be preserved this way.

Classic powder-pressed tablets are still the first choice for the mass market, as they can be produced time- and cost-efficiently in large quantities. However, individual therapy is not possible this way. Conventional solid dosage forms are complex systems made up of a wide variety of active ingredients and excipients [Qiu et al., 2016]. The development of a conventional formulation is therefore associated with a high level of effort due to possible cross-side effects.

For new drug development, a large number of animal and clinical studies are necessary before a suitable carrier system, a generic combination of active ingredients and a suitable release profile can be found. This is where pharmaceutical 2D/3D printing has a decisive economic advantage. Dosage forms

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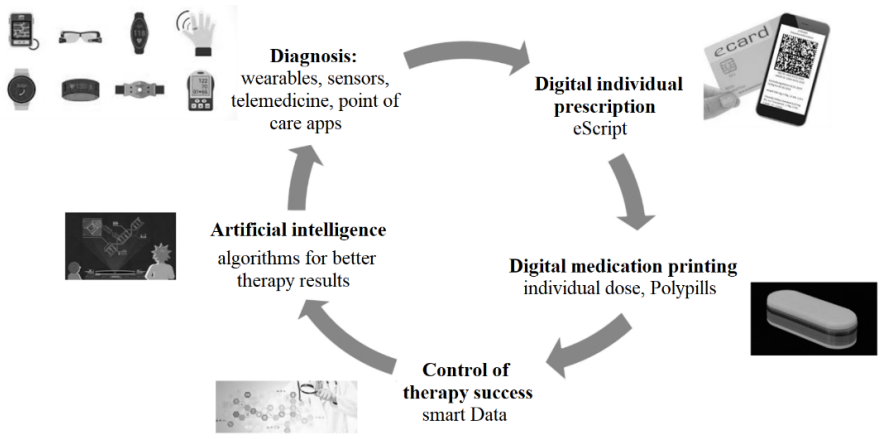

Figure 1: *The future of digital healthcare as a disruptive system including multiple steps to obtain optimal treatment individually tailored to the patient.*

would be developed, produced and modified at a minimum of cost and time.

INDIVIDUALIZED CARE – A DISRUPTIVE SYSTEM

In order to digitize the healthcare system as a whole, several separate players and stakeholders must be successfully linked. As part of a large multi-part disruptive system, the digital medication printing makes a decisive contribution to the personalization of medicine. Further important segments of the system as a whole include the use of artificial intelligence for data analysis, innovative methods for creating diagnoses and monitoring the success of therapy using smart data [Nohl-Deryk et al., 2018]. In a digitized healthcare system, active pharmaceutical ingredient systems are provided by supply companies for pharmacies, which manufacture tailored dosage forms on demand in small scales. While the doctor uses digitally obtained data to make an algorithm-based precision diagnosis for the patient, the data is forwarded directly to the formulator device in a pharmacy (see Figure 1). The reimbursement and big data collection for future optimization of diagnoses is carried out by the health insurance company [Baierlein, 2017]. Big data describes data sets that are, among other things, too large, complex, dynamic or loosely structured to be evaluated using conventional data processing methods and require innovative solutions therefore.

THE FUTURE OF HEALTH CARE

Medicine is a vivid science that lives from the introduction of innovations and new approaches and is therefore constantly developing. In the past, data acquisition in medicine was symptom-based and physicians depended their treatment on intuition. Today's diagnoses are made on the basis of patterns which results in actions based on evidence. Future application of rules, algorithms and big reference databases not only enable actionable clinical decision support but also individually efficient care [Wilckens, 2014]. Algorithms are going to convert personally generated data sets to precision treatment. Various studies indicate that integrating technology and digitalization have a positive impact on treatment success [Frias, 2017]. Wearable sensors and mobile gadgets already have been shown to increase therapeutic adherence in some cases. Nevertheless, there is still a long way to complete digitization of the health system [Kvedar et al., 2014].

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